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Canted-spin-caused electric dipoles: a local symmetry theory

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— A pair of magnetic atoms with canted spins $\mathbf{S}_a$ and $\mathbf{S}_b$ can give rise to an electric dipole moment **P.** Several forms for the dependence of $\mathbf{P}$ on the spins have been derived from various microscopic models, some of which have been invoked to explain experimental results found in some multiferroic materials. The forms are $\mathbf{P}_1 \propto \mathbf{R} \times (\mathbf{S_a} \times \mathbf{S}_b)$, $\mathbf{P}_2 \propto \mathbf{S_a} \times \mathbf{S}_b$, $\mathbf{P}_3 \propto \mathbf{S_a}(\mathbf{S_a} \cdot \mathbf{R}) - \mathbf{S}_b(\mathbf{S}_b \cdot \mathbf{R})$, where $\mathbf{R}$ is the relative position of the atoms. To unify and generalize these various forms we consider $\mathbf{P}$ as the most general quadratic function of the spin components that vanishes whenever $\mathbf{S_a}$ and $\mathbf{S}_b$ are collinear. The study reveals new forms. We generalize to the vector $\mathbf{P}$, Moriya's symmetry considerations on the (scalar) DM energy $\mathbf{D} \cdot \mathbf{S_a} \times \mathbf{S}_b$ (which led to restrictions on $\mathbf{D}$). This provides a rigorous proof that $\mathbf{P}_1$ is allowed no matter how high the symmetry of the atoms plus environment, and gives restrictions for all other contributions. The analysis leads to the suggestion of new terms omitted in the existing microscopic models, and predicts an unusual antiferroelectric ordering in the antiferromagnetically and ferroelectrically ordered phase of $RbFe(MoO_4)_2$.

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